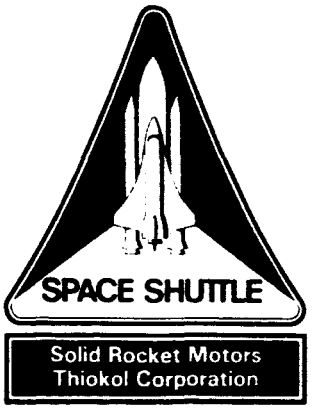
SA42/Royce Mitchell



TWR- 50288

NBR RUBBER SECONDARY VULCANIZATION EVALUATION TESTING

FINAL REPORT

DECEMBER 1989

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

Contract No. NAS8-30490

DR. No. Type [redacted] 5-3

WBS.No. 4B 201

Thiokol CORPORATION
SPACE OPERATIONS

P.O. Box 707, Brigham City, UT 84302-0707 (801) 863-3511

DOC NO. TWR-50288 VOL REV

TITLE PEI-985

NBR RUBBER SECONDARY VULCANIZATION EVALUATION TESTING

DECEMBER 1989

PREPARED BY

S. K. Jensen
Insulation & Lining Processing

APPROVED BY

G. R. JEPSON
INSULATION/LINING WORK CENTER

L. E. SEIDNER, SUPERVISOR
INSULATION & LINING PROCESSING

N. F. EDDY
INSULATION DESIGN

J. R. BRAITHWAITE
FLIGHT CERTIFICATION

D. M. MARSH
SRM PROGRAM OFFICE

R. D. LARSEN
SYSTEMS SAFETY

B. R. MCQUIVEY
SYSTEMS INTEGRATION

Thiokol CORPORATION
SPACE OPERATIONS
P.O. Box 707, Brigham City, UT 84302-0707 (801) 863-3511

RELIABILITY

J. G. TIBBITS
RELEASE
ECS NO. 1173

CONTENTS

Process Engineering Technical Report Categories
Aft Segment
Center Segment
Bond and Void Problems
Insulation
Adhesives
Forward Segment
Rubber, NBR
Vulcanization
Manufacturing Processes

1.0 INTRODUCTION AND SUMMARY

Occurrences of thin NBR insulation in the cylindrical areas of the 8B aft, 8A center, and 7B forward segments make it desirable to develop our ability to secondary vulcanize raw calendered NBR rubber into a previously cured NBR insulated segment. Impact to schedule and high costs of removing and replacing the insulation indicates the need to evaluate the feasibility of adding raw NBR insulation to provide required thicknesses of insulation in RSRM segments.

This testing evaluated insulation preparation and various coating combinations using three rubber thicknesses. This testing only evaluated applying the raw insulation over the pattern texture face of cured insulation.

It is concluded that using a wire brush and TCA solvent increases the bond strength and that either of the Chemlok combinations (one coat of 205 or one coat of 205 and one coat of 233) provide an adequate interface strength to cause cohesive failure when peeled at 45 degrees.

When secondary vulcanization is conducted directly onto the cured NBR pattern surface, it is recommended that the surface be prepared by cleaning with TCA solvent and a clean wire brush, and immediately drying with a clean low-lint cloth. It is also recommended that the Chemlok 233 and 205/233 surface coat combinations be further tested and evaluated by pull testing to better define the best system to use in providing maximum interface bond strength.

NOTE

The laboratory test results (Attachment I) were provided to Space Quality Statistical Engineering for evaluation of resulting data. Their observations and related comments are provided as Attachment II.

2.0 CONCLUSIONS

1. Secondary vulcanization of raw asbestos NBR to cured asbestos NBR using Chemlok 233 adhesive or Chemlok 205 primer, and 233 adhesive produces interface bond strengths sufficiently strong to cause cohesive failures at significant peel values.

2. Using a clean wire brush in the solvent cleaning step of the surface preparation improves the bond quality of a cured to secondary vulcanized asbestos NBR interface.

3. Use of tackifier allows an adhesive failure at the cured asbestos NBR rubber to secondary vulcanized asbestos NBR rubber interface.

3.0 RECOMMENDATIONS

It is recommended that:

1. Secondary bonding be qualified as a repair method rather than insulation removal when thin insulation occurs in RSRM segment insulation operations.

2. Further testing be conducted to identify the best Chemlok system to provide optimum secondary vulcanization interface bond reliability.

3. A clean wire brush be used during the solvent cleaning surface preparation operations to enhance the bondline quality.

4. Tackifier not be used as a mediator coating in cured asbestos NBR rubber to raw asbestos NBR rubber bonding surface preparation operations.

4.0 DISCUSSION

This testing was conducted in the Phase II full-scale edge unbond test segment after the testing outlined in WTP-0179A was completed. The tests were conducted per the test matrix provided as Table I.

4.1 Insulation Surface Preparation

a. The entire surface of the cured insulation surface where the samples were to be located was cleaned with TCA prior to the start of the test.

(1) The areas were thoroughly cleaned a second time with a dampened TCA low-lint cloth. Then, immediately dried with a clean dry low-lint cloth to ensure no solvent residue remained.

(2) The sample area was wetted with TCA and brushed thoroughly with a new (previously solvent cleaned) wire brush to remove any contaminants from the textured insulation surface and then thoroughly dried with a clean low-lint cloth.

4.2 Surface Coating Application

a. One coat of Chemlok 233 was brush applied tothe pre-determined areas of the cured NBR insulation of the segment. These surfaces were allowed to dry for a minimum of 30 minutes.

b. One coat of Chemlok 205 and one coat of Chemlok 233 were brush applied in the predetermined areas of the cured NBR insulation of the segment. Each individual coat of Chemlok was allowed to dry for a minimum of 30 minutes before the next subsequent operation was conducted.

c. Tackifier was brush applied on the cured insulation surface. The raw rubber was required to be laid on this surface within five to ten minutes after tackifier application.

4.3 Insulation Layup

NOTE

All rubber layup was laid so that the grain of the NBR rubber extended circumferentially in the segment (parallel to the direction of the sample pull).

Solvent (TCA) activation method and dry time was to the normal RSRM segment insulating process requirements. A two inch wide strip of Teflon tape was placed across the full width of each sample. This tab was placed at the tang side of each sample to ensure sample to sample consistency.

4.4 Vacuum Bagging

Dacron pattern cloth and 7777 Dacron breather cloth were placed over the entire insulation surface. The nylon vacuum bag was installed to extend from the OD of the case tang end to just forward of the tang end rubber layup onto the bare steel case.

4.5 Autoclave Cure

Cure was in the M-111 autoclave per the standard center segment cure cycle and requirements as monitored by the lagging sample thermocouple.

4.6 Sample Removal, Preparation And Peel Testing

NOTE

The surface of the cylinder did not have Chemlok; therefore, the previously cured insulation and subsequent secondary vulcanized samples could be removed from the test cylinder.

The insulation areas containing these test samples were removed from the test segment at H-7 and trimmed at Z-12 for bonding to witness panel plates. Each of the 14 samples were then bonded to a witness panel with EA 934NA and the secondary vulcanized layers cut into one-inch strips perpendicular to the grain of the NBR rubber. Peel testing was conducted at room temperature, at 45 degree angle, and at two inches per minute.

4.7 Test Results

The lab test results are included as Attachment I. Data from Samples 11 and 13 were not considered because of unexplainable inconsistency in peel testing data. Visual examination did not determine any explainable reason for the testing inconsistencies; however, the data from these two samples were not considered in the evaluation for these study results. All Chemlok combinations produced cohesive failures on resulting sample peels. Tackifier prepared samples failed in combination adhesive/cohesive failures, and the average (pli) stress was quite consistent when comparing the three thicknesses of samples pulled:

.300 inch thick 170 pli
.100 inch thick 81 pli
.050 inch thick 43 pli

TABLE I. Thin Area Repair Evaluation Test Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RUBBER PREPARATION														
TCA Clean with Rymple Cloth	X	X	X	X	X	X	X	X						
Wire Brush & TCA Clean/Dry with Rymple Cloth									X	X	X	X	X	X
CHEMLOK														
One Coat 233	X	X	X						X	X				
One Coat 205 then one Coat 233				X	X	X					X	X		
Tacklfier							X	X					X	X
RUBBER THICKNESSES														
.050 In. thick	X			X										
.100 In. thick		X			X		X		X		X		X	
.300 In. thick			X			X		X		X		X		X

Thiokol CORPORATION
SPACE OPERATIONS

ATTACHMENT I. R&D Laboratory - Test Result Data

Failure Mode Key

1 = Adhesive/Metal
2 = Cohesive/Adhesive
3 = Adhesive/Phenolic
4 = Cohesive/Phenolic
5 = Cohesive/Rubber
6 = Adhesive/Rubber
7 = Cohesive/Liner
8 = Adhesive/Liner
9 = Void
10 = Failure Comment
TB = Tab Broke
B = Button Side
P = Panel Side

LWR # : 583240
Work Order: B1174
Originator: Gary Purser

Date: 09/20/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
1	Panel #1		1.0000	39.4	39.4	39.4	0.0					100					TB
2	Panel #1		1.0000	42.0	42.0	42.0	0.0					100					TB
3	Panel #1		1.0000	42.7	42.7	42.7	0.0					100					TB
4	Panel #1		1.0000	43.5	43.5	43.5	0.0					100					TB
5	Panel #1		1.0000	40.6	40.6	40.6	0.0					100					TB
6	Panel #1		1.0000	43.5	43.5	43.5	0.0					100					TB
7	Panel #1		1.0000	41.9	41.9	41.9	0.0					100					TB
8	Panel #1		1.0000	42.3	42.3	42.3	0.0					100					TB
9	Panel #1		1.0000	41.2	41.4	41.3	0.0					100					TB
10	Panel #1		1.0000	43.9	44.1	44.0	0.0					100					TB
Average:				42.1	42.2	42.1						100					
Standard Deviation:				1.4	1.4	1.4											
Coeff. of Var:				3.36	3.41	3.38											

Date: 09/20/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
11	Panel #2		1.0000	89.0	90.2	89.8	0.2					100					TB
12	Panel #2		1.0700	85.9	87.6	86.8	0.4					100					TB
13	Panel #2		1.0000	83.5	85.8	84.7	0.2					100					TB
14	Panel #2		1.0000	82.3	85.8	84.0	0.1					100					TB
15	Panel #2		1.0000	83.5	84.2	83.8	0.2					100					TB
16	Panel #2		1.0000	83.6	84.3	84.0	0.2					100					TB
17	Panel #2		1.0200	79.2	81.5	80.5	0.2					100					TB
18	Panel #2		1.0000	63.6	78.8	75.1	0.3					100					TB
19	Panel #2		1.0000	81.2	82.5	81.8	0.2					100					TB
20	Panel #2		1.0000	83.5	86.5	85.1	0.2					100					TB
Average:				81.5	84.7	83.6						100					
Standard Deviation:				6.8	3.2	3.9											
Coeff. of Var:				8.37	3.82	4.66											

Prepared by the Mechanical Properties Characterization Section of the R&D Laboratories

PAGE 1

ATTACHMENT I. R&D Laboratory - Test Result Data (Continued)

Failure Mode Key

1 = Adhesive/Metal
2 = Cohesive/Adhesive
3 = Adhesive/Phenolic
4 = Cohesive/Phenolic
5 = Cohesive/Rubber
6 = Adhesive/Rubber
7 = Cohesive/Liner
8 = Adhesive/Liner
9 = Void
10 = Failure Comment
TB = Tab Broke
B = Button Side
P = Panel Side

LWR # : 583240
Work Order: B1174
Originator: Gary Purser

Date: 09/20/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
21	Panel #3		1.0000	163.9	177.0	170.8	2.5					100					
22	Panel #3		0.9900	156.9	165.7	160.7	2.5					100					
23	Panel #3		1.0000	156.7	165.3	161.7	2.5					100					
24	Panel #3		1.0000	154.3	159.5	156.7	2.5					100					
25	Panel #3		1.0000	152.3	163.9	158.3	2.5					100					
26	Panel #3		1.0000	153.4	166.9	158.2	2.5					100					
27	Panel #3		1.0200	153.0	172.0	162.7	2.5					100					
28	Panel #3		1.0000	152.9	166.1	159.7	2.5					100					
29	Panel #3		1.0000	159.9	173.7	164.5	2.5					100					
30	Panel #3		1.0000	161.9	171.3	167.6	2.5					100					
Average:				156.5	168.1	162.1						100					
Standard Deviation:				4.1	5.2	4.5											
Coeff. of Var:				2.63	3.11	2.75											

Date: 09/20/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
31	Panel #4		1.0000	42.6	42.6	42.6	0.0					100					TB
32	Panel #4		0.9900	45.2	45.2	45.2	0.0					100					TB
33	Panel #4		1.0100	42.1	42.1	42.1	0.0					100					TB
34	Panel #4		1.0000	43.7	43.7	43.7	0.0					100					TB
35	Panel #4		1.0000	41.8	41.8	41.8	0.0					100					TB
36	Panel #4		1.0000	43.8	43.8	43.8	0.0					100					TB
37	Panel #4		1.0000	38.6	40.1	39.6	0.0					100					TB
38	Panel #4		0.9800	46.4	46.4	46.4	0.0					100					TB
39	Panel #4		1.0000	45.4	46.1	45.7	0.0					100					TB
40	Panel #4		1.0000	41.8	43.0	42.4	0.0					100					TB
Average:				43.1	43.5	43.3						100					
Standard Deviation:				2.3	2.0	2.1											
Coeff. of Var:				5.22	4.57	4.77											

Prepared by the Mechanical Properties Characterization Section of the R&D Laboratories

PAGE 2

ATTACHMENT I. R&D Laboratory - Test Result Data (Continued)

Failure Mode Key

1 = Adhesive/Metal
2 = Cohesive/Adhesive
3 = Adhesive/Phenolic
4 = Cohesive/Phenolic
5 = Cohesive/Rubber
6 = Adhesive/Rubber
7 = Cohesive/Liner
8 = Adhesive/Liner
9 = Void
10 = Failure Comment
TB = Tab Broke
B = Button Side
P = Panel Side

LWR # : 583240
Work Order: B1174
Originator: Gary Purser

Date: 09/20/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
41	Panel #5		1.0000	80.9	84.2	83.2	0.2					100					TB
42	Panel #5		1.0000	76.8	79.1	77.9	0.2					100					TB
43	Panel #5		1.0000	79.1	80.7	80.0	0.1					100					TB
44	Panel #5		1.0000	80.1	83.2	82.2	0.2					100					TB
45	Panel #5		1.0000	79.6	81.4	80.5	0.2					100					TB
46	Panel #5		1.0000	82.3	83.9	83.0	0.2					100					TB
47	Panel #5		1.0000	79.6	81.3	80.4	0.1					100					TB
48	Panel #5		1.0000	83.2	84.0	83.5	0.1					100					TB
49	Panel #5		1.0000	82.4	86.2	85.0	0.3					100					TB
50	Panel #5		1.0000	81.5	82.9	82.3	0.2					100					TB
Average:				80.5	82.7	81.8						100					
Standard Deviation:				1.9	2.1	2.1											
Coeff. of Var:				2.39	2.50	2.56											

Date: 09/21/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
51	Panel #6		1.0000	170.5	180.8	175.8	2.5					100					
52	Panel #6		1.0200	166.3	179.1	171.7	2.5					100					
53	Panel #6		1.0000	164.8	177.3	170.2	2.5					100					
54	Panel #6		1.0000	159.4	169.9	165.5	2.5					100					
55	Panel #6		0.9800	155.8	165.7	161.2	2.5					100					
56	Panel #6		1.0000	161.5	170.2	165.8	2.5					100					
57	Panel #6		1.0000	159.0	168.6	162.6	2.5					100					
58	Panel #6		1.0000	163.9	172.7	168.0	2.5					100					
59	Panel #6		0.9700	164.0	171.4	166.9	2.5					100					
60	Panel #6		1.0000	163.2	173.3	167.4	2.5					100					
Average:				162.8	172.9	167.5						100					
Standard Deviation:				4.2	4.8	4.3											
Coeff. of Var:				2.55	2.79	2.56											

Prepared by the Mechanical Properties Characterization Section of the R&D Laboratories

PAGE 3

ATTACHMENT I. R&D Laboratory - Test Result Data (Continued)

Failure Mode Key

1 = Adhesive/Metal
2 = Cohesive/Adhesive
3 = Adhesive/Phenolic
4 = Cohesive/Phenolic
5 = Cohesive/Rubber
6 = Adhesive/Rubber
7 = Cohesive/Liner
8 = Adhesive/Liner
9 = Void
10 = Failure Connect
TB = Tab Broke
B = Button Side
P = Panel Side

LWR # : 583240
Work Order: B1174
Originator: Gary Purser

Date: 09/21/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
61	Panel #7		0.9800	83.2	86.2	84.9	0.2					50	50				TB
62	Panel #7		0.9600	80.7	82.0	81.2	0.1					50	50				TB
63	Panel #7		1.0300	81.3	82.2	81.8	0.1					40	60				TB
64	Panel #7		0.9800	81.9	83.4	82.9	0.2					30	70				TB
65	Panel #7		1.0100	81.6	84.0	83.1	0.2					30	70				TB
66	Panel #7		1.0000	78.0	83.5	80.7	1.3					20	80				TB
67	Panel #7		1.0200	77.1	82.4	79.3	1.2					20	80				TB
68	Panel #7		1.0200	79.4	81.8	80.8	0.3					40	60				TB
69	Panel #7		1.0000	78.3	82.4	80.4	0.6					20	80				TB
70	Panel #7		1.0300	77.7	82.9	80.9	0.8					20	80				TB
Average:				79.9	83.1	81.6						32	68				
Standard Deviation:				2.1	1.3	1.6											
Coeff. of Var:				2.62	1.57	1.99											

Date: 09/21/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
71	Panel #8		1.0000	153.4	161.0	157.2	2.5					30	70				
72	Panel #8		1.0000	154.2	165.5	160.1	2.5					30	70				
73	Panel #8		1.0400	145.5	156.3	152.5	2.5					30	70				
74	Panel #8		1.0000	148.0	160.7	155.5	2.5					40	60				
75	Panel #8		1.0200	150.1	162.1	155.7	2.5					30	70				
76	Panel #8		1.0000	153.1	159.5	156.3	2.5					30	70				
77	Panel #8		0.9700	154.6	161.3	157.9	2.5					30	70				
78	Panel #8		1.0000	150.2	157.7	154.8	2.5					30	70				
79	Panel #8		0.9800	158.0	164.1	161.3	2.5					30	70				
80	Panel #8		1.0000	159.1	165.2	162.0	2.5					30	70				
Average:				152.6	161.3	157.3						31	69				
Standard Deviation:				4.3	3.0	3.0											
Coeff. of Var:				2.79	1.89	1.92											

Prepared by the Mechanical Properties Characterization Section of the R&D Laboratories

PAGE 4

ATTACHMENT I. R&D Laboratory - Test Result Data (Continued)

Failure Mode Key

		1 = Adhesive/Metal	5 = Cohesive/Rubber	9 = Void	
LWR # :	583240	2 = Cohesive/Adhesive	6 = Adhesive/Rubber	10 = Failure Comment	
Work Order:	B1174	3 = Adhesive/Phenolic	7 = Cohesive/Liner	TB = Tab Broke	
Originator:	Gary Purser	4 = Cohesive/Phenolic	8 = Adhesive/Liner	B = Button Side	
				P = Panel Side	

Date: 09/21/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
81	Panel #9		1.0300	77.6	79.1	78.3	0.1					100					TB
82	Panel #9		1.0000	83.9	86.5	85.2	0.3					100					TB
83	Panel #9		1.0400	82.9	86.3	85.0	0.3					100					TB
84	Panel #9		1.0300	80.8	82.6	81.9	0.4					100					TB
85	Panel #9		1.0200	81.5	85.2	83.4	0.4					100					TB
86	Panel #9		0.9900	82.2	86.4	84.2	0.4					100					TB
87	Panel #9		1.0000	81.9	85.3	83.6	0.3					100					TB
88	Panel #9		1.0000	78.5	79.8	79.1	0.1					100					TB
89	Panel #9		1.0000	83.0	84.8	84.1	0.2					100					TB
90	Panel #9		1.0000	82.5	83.7	83.1	0.3					100					TB
Average:				81.5	84.0	82.8						100					
Standard Deviation:				2.0	2.7	2.4											
Coeff. of Var:				2.47	3.19	2.85											

Date: 09/21/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
91	Panel #10		1.0000	160.6	184.9	169.7	2.5					100					
92	Panel #10		1.0000	161.3	173.8	168.3	2.5					100					
93	Panel #10		1.0000	157.6	169.7	163.3	1.9					100					
94	Panel #10		1.0000	159.3	175.9	167.9	1.9					100					
* 95	Panel #10		1.0000	-4.8	222.3	113.8	.3					100					TB
96	Panel #10		1.0000	188.9	205.7	196.6	3					100					
97	Panel #10		1.0000	165.8	176.8	172.1	3					100					
98	Panel #10		1.0000	162.3	181.0	170.6	3					100					
99	Panel #10		1.0000	162.9	181.0	169.5	3					100					
100	Panel #10		1.0000	163.0	174.5	168.2	3					100					
Average:				164.6	180.4	171.8						100					
Standard Deviation:				9.4	10.5	9.6											
Coeff. of Var:				5.72	5.83	5.60											

* Excluded from average SEE COMMENT ON PAGE 7

Prepared by the Mechanical Properties Characterization Section of the R&D Laboratories

PAGE 5

ATTACHMENT I. R&D Laboratory - Test Result Data (Continued)

Failure Mode Key

		1 = Adhesive/Metal	5 = Cohesive/Rubber	9 = Void
LMR # :	583240	2 = Cohesive/Adhesive	6 = Adhesive/Rubber	10 = Failure Comment
Work Order:	B1174	3 = Adhesive/Phenolic	7 = Cohesive/Liner	TB = Tab Broke
Originator:	Gary Purser	4 = Cohesive/Phenolic	8 = Adhesive/Liner	B = Button Side
				P = Panel Side

Date: 09/21/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
101	Panel #11		1.0000	-0.1	133.1	69.8	0									100	TB
102	Panel #11		1.0000	0.0	133.0	69.0	0									100	TB
103	Panel #11		1.0000	-0.1	132.3	58.2	0									100	TB
104	Panel #11		1.0000	0.8	137.0	72.5	0									100	TB
105	Panel #11		1.0000	0.7	134.8	65.0	0									100	TB
106	Panel #11		1.0000	-4.1	132.8	54.8	0									100	TB
107	Panel #11		1.0000	-0.4	134.9	67.8	0									100	TB
108	Panel #11		1.0000	-0.5	122.9	52.3	0									100	TB
109	Panel #11		1.0000	-2.1	134.2	63.6	0									100	TB
110	Panel #11		1.0000	-3.9	139.4	61.8	0									100	TB
Average:				-1.0	133.5	63.5										100	
Standard Deviation:				1.8	4.3	6.7											
Coeff. of Var:				-182.50	3.21	10.57											

Date: 09/21/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
111	Panel #12		1.0000	176.1	193.2	183.7	3					100					
112	Panel #12		1.0000	168.2	189.4	177.6	3					100					
113	Panel #12		1.0000	166.2	178.1	171.7	3					100					
114	Panel #12		1.0000	171.8	189.2	179.9	2					100					
115	Panel #12		1.0400	162.2	174.0	168.4	2.5					100					
116	Panel #12		1.0200	165.9	184.8	174.1	2.5					100					
117	Panel #12		1.0000	164.3	187.3	173.3	2.7					100					
118	Panel #12		1.0300	167.1	179.8	173.5	2.5					100					
119	Panel #12		1.0000	170.4	182.6	174.0	2.5					100					
120	Panel #12		1.0700	165.1	176.2	171.8	2.5					100					
Average:				167.7	183.5	174.8						100					
Standard Deviation:				4.1	6.4	4.4											
Coeff. of Var:				2.43	3.48	2.54											

Prepared by the Mechanical Properties Characterization Section of the R&D Laboratories

PAGE 6

ATTACHMENT I. R&D Laboratory - Test Result Data (Continued)

Failure Mode Key

1 = Adhesive/Metal
2 = Cohesive/Adhesive
3 = Adhesive/Phenolic
4 = Cohesive/Phenolic
5 = Cohesive/Rubber
6 = Adhesive/Rubber
7 = Cohesive/Liner
8 = Adhesive/Liner
9 = Void
10 = Failure Comment
TB = Tab Broke
B = Button Side
P = Panel Side

LWR # : 583240
Work Order: B1174
Originator: Gary Purser

Date: 09/25/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
‡121	Panel #13		1.0000	81.0	84.0	82.6	0.2					20	80				TB
122	Panel #13		1.0200	73.1	80.3	77.0	2.0					30	70				
123	Panel #13		1.0200	73.4	81.3	76.8	2.0					30	70				
124	Panel #13		1.0000	72.9	79.3	76.7	2.0					30	70				
‡125	Panel #13		1.0200	79.5	81.9	81.0	0.3					30	70				TB
‡126	Panel #13		1.0000	79.1	83.5	82.0	0.2					30	70				TB
‡127	Panel #13		1.0400	69.1	71.5	70.3	0.1					20	80				TB
‡128	Panel #13		1.0000	74.0	76.8	75.2	0.1					20	80				TB
‡129	Panel #13		1.0000	78.7	83.1	81.4	0.5					30	70				TB
‡130	Panel #13		1.0000	75.2	81.8	78.2	1.0					30	70				TB
Average:				73.1	80.3	76.8						30	70				
Standard Deviation:				0.2	1.0	0.1											
Coeff. of Var:				0.33	1.20	0.19											

Date: 09/25/89 Test Machine: Riehle Temperature: 73 Deg. F
Technician: M.Davis Test Type: 45 Degree Peel Crosshead Speed: 2.0 in/min

Spec No.	Segment ID.	Panel ID. Serial	Width (in)	Min Stress (pli)	Max Stress (pli)	Avg Stress (pli)	Inches Peeled	Failure Mode Analysis 1	2	3	4	5	6	7	8	9	10
131	Panel #14		1.0000	177.8	203.3	193.8	0.4					30	70				TB
132	Panel #14		1.0000	173.7	197.1	189.2	0.2					30	70				TB
133	Panel #14		0.9900	187.5	204.0	200.1	0.2					30	70				TB
134	Panel #14		1.0400	138.9	207.1	183.8	0.9					20	80				TB
135	Panel #14		1.0000	144.6	207.1	184.9	0.8					20	80				TB
136	Panel #14		1.0200	114.1	206.5	160.4	1.0					20	80				TB
137	Panel #14		1.0000	158.1	214.0	203.7	0.7					20	80				TB
138	Panel #14		1.0000	145.8	217.2	190.3	0.8					20	80				TB
139	Panel #14		0.9900	155.8	218.3	200.1	0.7					20	80				TB
140	Panel #14		1.0000	131.6	212.3	184.9	0.8					20	80				TB
Average:				152.8	208.7	189.1						23	77				
Standard Deviation:				22.5	6.7	12.3											
Coeff. of Var:				14.74	3.20	6.51											

‡ Excluded from average ON SAMPLES WHERE THE SAMPLE PEEL BREAKS WITH LITTLE OR NO PEELING ONLY THE MAX STRESS (PLI) IS A VALID TEST RESULT.

Prepared by the Mechanical Properties Characterization Section of the R&D Laboratories

PAGE 7

ATTACHMENT II. Memo 8863-FY90-M046 Bond Strength

Thiokol CORPORATION
SPACE OPERATIONS

11 Oct 1989
8863-FY90-M046

TO: S. K. Jensen

FROM: D. S. Brown
Extension 5813

SUBJECT: Bond Strength

REVIEW

A test matrix of 14 different combinations was set up and ten measurements were taken at each combination (see Table 1). Panel 11 and panel 13 were not included in the analysis because there is a concern about the validity of these measurements. Also, panel 10 had one measurement which was not included in the analysis. The average stress values were analyzed.

CONCLUSIONS

It is obvious that rubber thickness is a significant factor. Level 3 (.300 in.) yields larger values than level 2 (.100 in.) and level 1 (.050 in.). Also, level 2 yields larger values than level 1.

The following comments are my subjective opinion. Valid statistical tests could not be performed.

I believe that rubber preparation is a significant factor for rubber thickness of .300 in. Panel 3 and panel 10 were compared to each other, panel 6 and panel 12 were compared, and panel 8 and panel 14 were compared. These three comparisons indicated that the panels which had the wire brush yielded larger values than the panels without the wire brush. I believe that rubber preparation is not a significant factor for rubber thicknesses of .050 and .100.

I believe that Chemlok may be a significant factor for rubber thickness of .300 in. Panel 3, panel 6, and panel 8 were compared and panel 10, panel 12, and panel 14 were compared. These two comparisons indicated that the three levels of Chemlok yield different results, however, it is not clear which level yields larger values. I believe that Chemlok is not a significant factor for rubber thicknesses of .050 and .100.

DISCUSSION

In comparing within a factor, the simultaneous effect of the other factors has not been included. This invalidates any statistical comparison, but it does allow for some general observations. The data is in Table 2.

Duane S. Brown

Duane S. Brown

ATTACHMENT II. Memo 8863-FY90-M046 Bond Strength (Continued)

Table 1

	Panel													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Rubber Preparation														
1) TCA Clean with Rymple Cloth	x	x	x	x	x	x	x	x						
2) Wire Brush & TCA Clean/Dry with Rymple Cloth									x	x	x	x	x	x
Chemlok														
1) One Coat 233	x	x	x						x	x				
2) One Coat 205 then one Coat 233				x	x	x					x	x		
3) Tackifier							x	x					x	x
Rubber Thickness														
1) .050 in.	x			x										
2) .100 in.		x			x		x		x		x		x	
3) .300 in.			x			x		x		x		x		x

ATTACHMENT II. Memo 8863-FY90-M046 Bond Strength (Continued)

Table 2

Panel

1	2	3	4	5	6
39.4	89.8	170.8	42.6	83.2	175.8
42.0	86.8	160.7	45.2	77.9	171.7
42.7	84.7	161.7	42.1	80.0	170.2
43.5	84.0	156.7	43.7	82.2	165.5
40.6	83.8	158.3	41.8	80.5	161.2
43.5	84.0	158.2	43.8	83.0	165.8
41.9	80.5	162.7	39.6	80.4	162.6
42.3	75.1	159.7	46.4	83.5	168.0
41.3	81.8	164.5	45.7	85.0	166.9
44.0	85.1	167.6	42.4	82.3	167.4

Panel

7	8	9	10	12	14
84.9	157.2	78.3	169.7	183.7	193.8
81.2	160.1	85.2	168.3	177.6	189.2
81.8	152.5	85.0	163.3	171.7	200.1
82.9	155.5	81.9	167.9	179.9	183.8
83.1	155.7	83.4	196.6	168.4	184.9
80.7	156.3	84.2	172.1	174.1	160.4
79.3	157.9	83.6	170.6	173.3	203.7
80.8	154.8	79.1	169.5	173.5	190.3
80.4	161.3	84.1	168.2	174.0	200.1
80.9	162.0	83.1		171.8	184.9